

TEMPORAL CONTROL OF BEHAVIOR: SCHEDULE INTERACTIONS¹

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In Experiment I the response that terminated the postreinforcement pauses occurring under a fixed-interval 60-second schedule was reinforced, if the pause duration exceeded 30 seconds. The percentage of such pauses, rather than increasing, decreased. There were complex effects on the discriminative control of the pause by the reinforcer terminating the previous fixed interval, depending on whether the fixed interval and the added reinforcer were the same or different. In Experiments II(a) and II(b), each reinforcement initiated an alternative fixed-interval interresponse-time-greater-than-t-sec schedule, the schedule values being systematically varied. When the response following a pause exceeding a given duration was reinforced, fewer such pauses occurred than when they were not reinforced, *i.e.*, on the comparable simple fixed-interval schedule. There was no systematic relationship between mean interreinforcement interval and duration of the postreinforcement pause. The pause duration initiated by reinforcement was directly related to the dependency controlling the shortest pause at that time, regardless of changes in mean interreinforcement interval.

Key words: postreinforcement pause, discriminative control, temporal control, natural response rate, fixed interval, interresponse time greater than t seconds, rats

Under a fixed-interval (FI) schedule, the first response is reinforced either after a stated minimum interval has elapsed since previous reinforcement, or, in the case of FI schedules timed "by the clock", in each of successive equal intervals. This schedule has attracted considerable research interest, mainly because FI performance is thought to provide evidence about temporal discrimination; that is, the ways in which an organism's behavior adjusts to the temporal contingencies operating in a given situation. Typically, performance in a single interval of the FI schedule begins with a pause (the postreinforcement pause) and ends in a steady and rather high response rate. Two aspects of this pattern have been studied in some detail: the transition from the pause to the high response rate, and determination of the duration of the postreinforcement pause. Responding following the

postreinforcement pause is usually accelerated, forming the characteristic FI scallop (Branch and Gollub, 1974; Dews, 1968; Ferster and Skinner, 1957; Lowe and Harzem, 1977), although it should be noted that according to some investigators the transition is abrupt, and the FI pattern is better described as break-and-run (Schneider, 1969; Shull and Brownstein, 1970; Shull, Guilkey, and Witty, 1972). The postreinforcement pause, on the other hand, is typically long, occupying about half to two-thirds of the interval. The duration of the pause is systematically related to the duration of the fixed interval, and it is affected by variables such as reinforcer magnitude (Lowe, Davey, and Harzem, 1974; Staddon, 1970), level of deprivation (Collier, 1962), drug effects (Branch and Gollub, 1974; Dews, 1968), and punishment of each response (Azrin and Holz, 1961).

Although the performance characteristics of FI schedules have been studied extensively, determination of the duration of the postreinforcement pause is not yet fully understood. Consider, for example, the following comparison with the performance that is typically observed under interresponse-time-greater-than-t-sec ($IRT > t$) schedules. Under an FI schedule, the pause often occupies half

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or more of the duration of the interval. Thus, under an FI 60-sec schedule, for example, almost every pause exceeds 20 sec. Yet, when a pause of 20 sec is necessary for reinforcement, *i.e.*, under the $IRT > 20$ -sec schedule, considerably fewer pauses of such length are observed, only half or fewer of the interresponse times (IRTs) meeting the schedule criterion and thereby ending in reinforcement (Harzem, 1969; Kramer and Rilling, 1970). Also, if FI and $IRT > t$ schedules with the same parameter are compared, considerably fewer postreinforcement pauses matching in duration the schedule value are observed under the FI schedule than under the $IRT > t$ schedule (Harzem, 1969; Kramer and Rilling, 1970; see also Richardson, 1973). Thus, in summary, although an organism can repeatedly pause for a given duration or longer under an FI schedule, it fails to pause for the same duration with the same high frequency when that pause duration is *required* for reinforcement on an $IRT > t$ schedule. Conversely, although an organism can frequently meet the schedule criterion under an $IRT > t$ schedule, its pauses are shorter under an FI schedule with the same parameter.

The main difference between the $IRT > t$ and FI schedules is that pauses of a given duration or longer are required for reinforcement in the $IRT > t$ schedule, whereas in the FI schedule there is no such requirement. The first experiment was designed to investigate possible interactions between FI and $IRT > t$ schedules. Specifically, the question was whether the duration of the FI pause would increase if responses terminating longer pause durations were directly reinforced, in addition to the FI reinforcement.

EXPERIMENT I: DIRECT REINFORCEMENT OF RESPONSES THAT TERMINATED CRITERION POSTREINFORCEMENT PAUSES

METHOD

Subjects

Eight male hooded rats, approximately 12 weeks old at the start of the experiment, were individually housed and maintained at 80% of their free-feeding weights. Water was freely available in the home cages.

Apparatus

Four Lehigh Valley Model 143-25 chambers, with the right lever and both pellet dispenser and milk dipper in position, were used. The milk dipper remained in the up position and operated at each reinforcement, the dipping action taking approximately 1.0 sec. The houselight remained off throughout the experiment. The experiment was controlled by and the data were recorded and analyzed on a NOVA 1200 computer.

Procedure

Lever-pressing responses were shaped in the first session. Subsequently, the animals were placed under an FI 60-sec schedule in daily sessions including weekends (First Baseline condition). Throughout the experiment, the FI reinforcer was a 45-mg Noyes pellet. When inspection of cumulative records indicated that responding was stable, the following stability criteria were applied: (i) variation in the mean duration of postreinforcement pauses in five successive sessions less than 10% of the mean duration for all five sessions; (ii) variation between response rates in each of the same five sessions less than 10% of the mean rate for all five sessions. When according to these criteria responding had become stable, a second reinforcement contingency was added, while at the same time FI reinforcement continued. The response terminating a postreinforcement pause was reinforced if the duration of the pause exceeded 30 sec. For the added reinforcement, two types of reinforcer were used: a 45-mg Noyes pellet, which was the same as for FI reinforcement (Food condition), and 0.01 ml of 30% solution in water of Nestlé's condensed milk (Milk condition). Four animals (P6, P9, P11, and P15) were first placed on the Milk, and then on the Food condition. The other four animals (P16, P17, P18, P19) were exposed to these conditions in reverse order. Finally, the added reinforcement was removed and 15 further sessions were conducted under the FI 60-sec schedule (Second Baseline). Sessions lasted 100 min or until a total of 100 reinforcements occurred, including the added reinforcements, whichever came first. Each change in experimental conditions was carried out only after the stability criterion described above was met. The number of ses-

sions under each condition is shown in Table 1.

Table 1

Experiment I: number of sessions, interquartile range of postreinforcement pauses (seconds), and running rates (responses per minute) on each condition. BL₁: First Baseline FI 60-sec. BL₂: Second Baseline FI 60-sec. The order of conditions is shown top to bottom.

Animal	Condition	No. Sessions	Interquartile Ranges of Pauses Following		Running Rate Following	
			FI rft.	Added rft.	FI rft.	Added rft.
P6	BL ₁	25	29.0-54.5		41.4	
	MILK	35	23.5-36.5	3.0- 7.0	35.6	47.8
	FOOD	22	16.0-26.0	16.0-25.5	49.1	8.0
	BL ₂	15	29.0-44.7		78.5	
P9	BL ₁	25	25.0-46.5		61.8	
	MILK	35	22.0-31.0	12.0-20.0	53.4	52.5
	FOOD	22	16.0-22.0	17.5-25.5	56.6	18.8
	BL ₂	15	25.7-40.5		92.6	
P11	BL ₁	27	22.0-41.0		50.9	
	MILK	35	23.0-33.0	13.0-18.0	28.8	38.7
	FOOD	22	16.0-26.7	17.7-23.5	48.9	10.2
	BL ₂	15	31.2-44.7		89.3	
P15	BL ₁	28	28.5-60.0		33.4	
	MILK	35	24.1-36.0	10.7-23.0	33.2	49.6
	FOOD	22	23.0-34.2	25.0-36.0	44.3	12.4
	BL ₂	15	34.0-61.0		93.3	
P16	BL ₁	26	31.0-43.0		81.6	
	FOOD	35	18.0-29.0	8.5-24.7	56.4	12.7
	MILK	22	19.0-30.5	5.0-13.0	84.5	60.1
	BL ₂	15	29.0-41.0		115.1	
P17	BL ₁	26	15.0-34.5		61.4	
	FOOD	35	22.0-31.0	18.2-24.0	66.6	29.9
	MILK	22	25.7-32.0	3.6- 6.0	101.4	88.7
	BL ₂	15	24.0-37.5		105.9	
P18	BL ₁	26	23.0-47.0		42.6	
	FOOD	35	7.0-31.0	4.7-16.1	41.6	8.4
	MILK	22	23.5-36.2	3.0- 4.0	50.9	68.3
	BL ₂	15	17.5-47.7		71.5	
P19	BL ₁	26	24.5-39.0		81.6	
	FOOD	35	22.0-34.0	28.0-33.7	56.4	13.9
	MILK	22	26.2-43.0	4.0- 6.2	84.5	75.7
	BL ₂	15	41.0-54.0		115.1	

RESULTS AND DISCUSSION

Figure 1 shows the percentage of pauses following FI reinforcement that were longer than 30 sec in the baseline FI 60-sec schedule (Second Baseline), and in the Food and Milk conditions. When responses terminating pauses longer than 30 sec were reinforced, the frequency of such pauses declined in relation to their frequency on the FI schedule. This decline was greater when FI reinforcement

and added reinforcement were the same, *i.e.*, food, than when FI reinforcement and added reinforcement were different, *i.e.*, food and milk respectively. This difference probably represents a confusion of the discriminative control by the reinforcer in the Food condition (*cf.* Cruse, Vitulli, and Dertke, 1966). In this condition, the presentation of the food pellet signalled either of two different situations, depending on whether reinforcement occurred on completion of a fixed-interval run, or on completion of a pause that met the added reinforcement criterion.

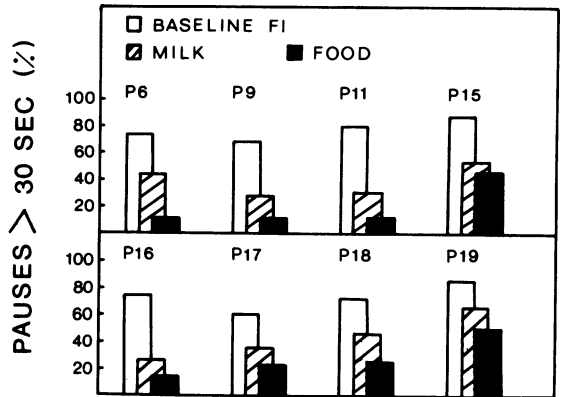


Fig. 1. Experiment I: percentage of pauses that exceeded 30 sec on the simple FI 60-sec schedule (Second Baseline) and when responses ending such pauses were reinforced with milk and with food. Data are from the last three sessions under each condition.

Evidence of such discriminative control is seen in Figure 2, which shows the mean duration of the postreinforcement pauses in the last three sessions of each condition. The interquartile ranges of these durations, as well as running rates are given in Table 1. (The running rates were calculated after excluding the pauses.) With the exception of one data point (Animal P17), the pauses following FI reinforcement were longer under the simple FI 60-sec schedule than with either type of added reinforcement.

In the Milk condition, that is, when the added reinforcer was different from the FI reinforcer, the pauses were longer following FI reinforcement than following added reinforcement. The relationship was more complex, however, in the Food condition, and depended on which of the two conditions was experienced first by the animals. If the animals had been previously trained under the Milk condition, the postreinforcement pauses

under the Food condition were of identical duration, regardless of whether they followed FI reinforcement or added reinforcement. For animals that first experienced the Food condition, on the other hand, there was a difference between the aftereffects of FI reinforcement and added reinforcement even though the reinforcer was the same in the Food condition, the pause following FI reinforcement was longer than that following added reinforcement. Thus, there was an order-effect in the establishment of discriminative control by the reinforcing stimuli. When the FI reinforcer and the added reinforcer were identical, as in the Food condition, such discriminative control could be based on the events that preceded reinforcement: added reinforcement was preceded by a pause 30 sec or longer, whereas FI reinforcement was preceded by a run of responses. Discrimination based on these cues alone was not established, however, if the animals were first trained with two different kinds of reinforcers, and initially learned a discrimination on the basis of the difference between the types of reinforcers; it is possible that the failure of the discrimination to develop in these animals may repre-

sent an instance of "blocking" (*cf.* Mackintosh, 1974).

EXPERIMENT II(a) REINFORCEMENT BASED ON DURATION ON ALTERNATIVE FI IRT > t SCHEDULES

In Experiment I, a confusion of the discriminative effect of reinforcement was observed because the contingencies that prevailed after reinforcement were not always the same. Following FI reinforcement, a response terminating either a minimum pause of 30 sec, or a minimum interval of 60 sec regardless of intervening responses, was reinforced; following added reinforcement, a response terminating an interval shorter than 30 sec, regardless of intervening responses, led to reinforcement. Confusion of these contingencies was reduced if they were initiated by different kinds of reinforcers. In the present experiment, on the other hand, possibility of such confusion was eliminated by holding constant the contingencies that prevailed after every reinforcement. The minimum pause

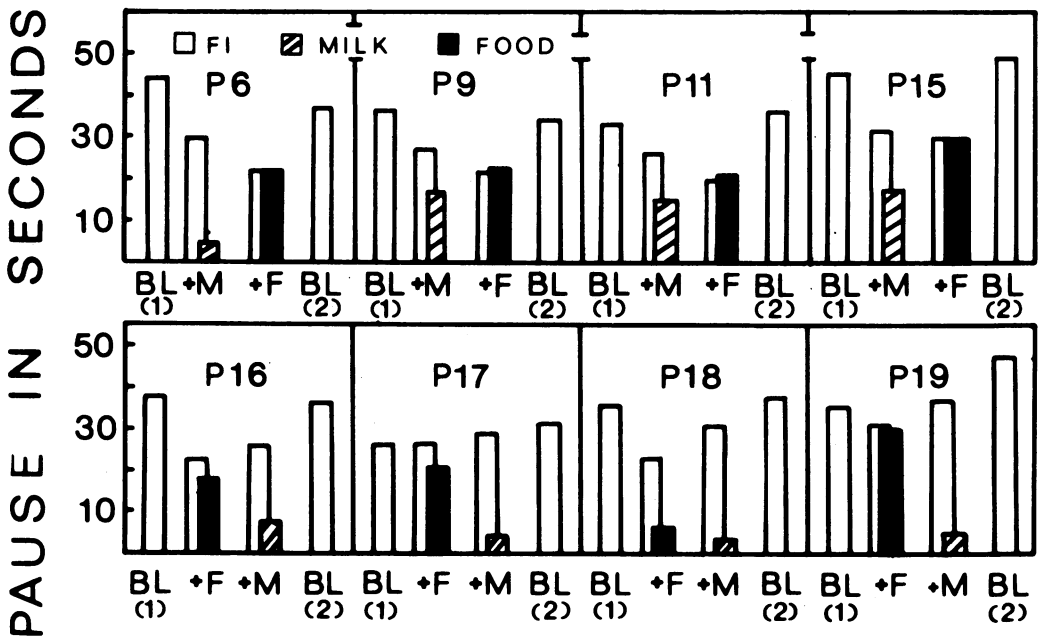


Fig. 2. Experiment I: mean duration of postreinforcement pauses under the baseline FI 60-sec schedules (BL₁ and BL₂) and under the Milk and Food Conditions. Cross hatched and filled blocks indicate mean duration of postreinforcement pauses that occurred following added milk and food respectively; open blocks indicate mean duration of postreinforcement pauses following FI reinforcement. The sequence of conditions is shown left to right on the abscissa.

duration required for added reinforcement was varied over a wide range of values.

METHOD

Subjects

Four naive male hooded rats, approximately 90 days old at the start of the experiment, were individually housed and maintained at 80% of their free-feeding weights. Water was freely available in the home cages.

Apparatus and Procedure

The apparatus was the same as in Experiment I. Throughout this experiment, the reinforcer was a 45-mg Noyes pellet. In the first session, lever-pressing responses were shaped. Starting with the second session, the animals were trained under an FI 60-sec schedule until responding became stable (First Baseline). The animals were then placed under an alternative fixed-interval 60-sec interresponse-time-greater-than-X-sec (*alt* FI 60-sec IRT > X-sec) schedule. That is, following each reinforcement, either the next response was reinforced provided it occurred after a pause of at least X sec, or, if the pause was shorter than X sec, the first response to occur after an interval of 60 sec from the previous reinforcer was reinforced. (Note that this is a modified version of the alternative schedule described by Ferster and Skinner, 1957. Strictly speaking, the present schedule is a "reinforcement-initiated alternative schedule".) Thus, unlike Experiment I, each reinforcement initiated the same two contingencies.

The FI value was held constant at 60 sec throughout the experiment, but the IRT > t value (X) was 30, 20, 40, 10, and 50 sec, occurring in that order. Each change in the value of X was made after the stability criterion described in Experiment I was met. Finally, the IRT > t contingency was removed and 10 further sessions were conducted under an FI 60-sec schedule (Second Baseline). The number of sessions on each condition is shown in Table 2. The sessions were conducted daily and each session lasted 100 min or until 100 reinforcements occurred, whichever came first.

RESULTS AND DISCUSSION

Figure 3 shows cumulative records of the performance of Animal P2 in the last session under each schedule value and under the

Table 2

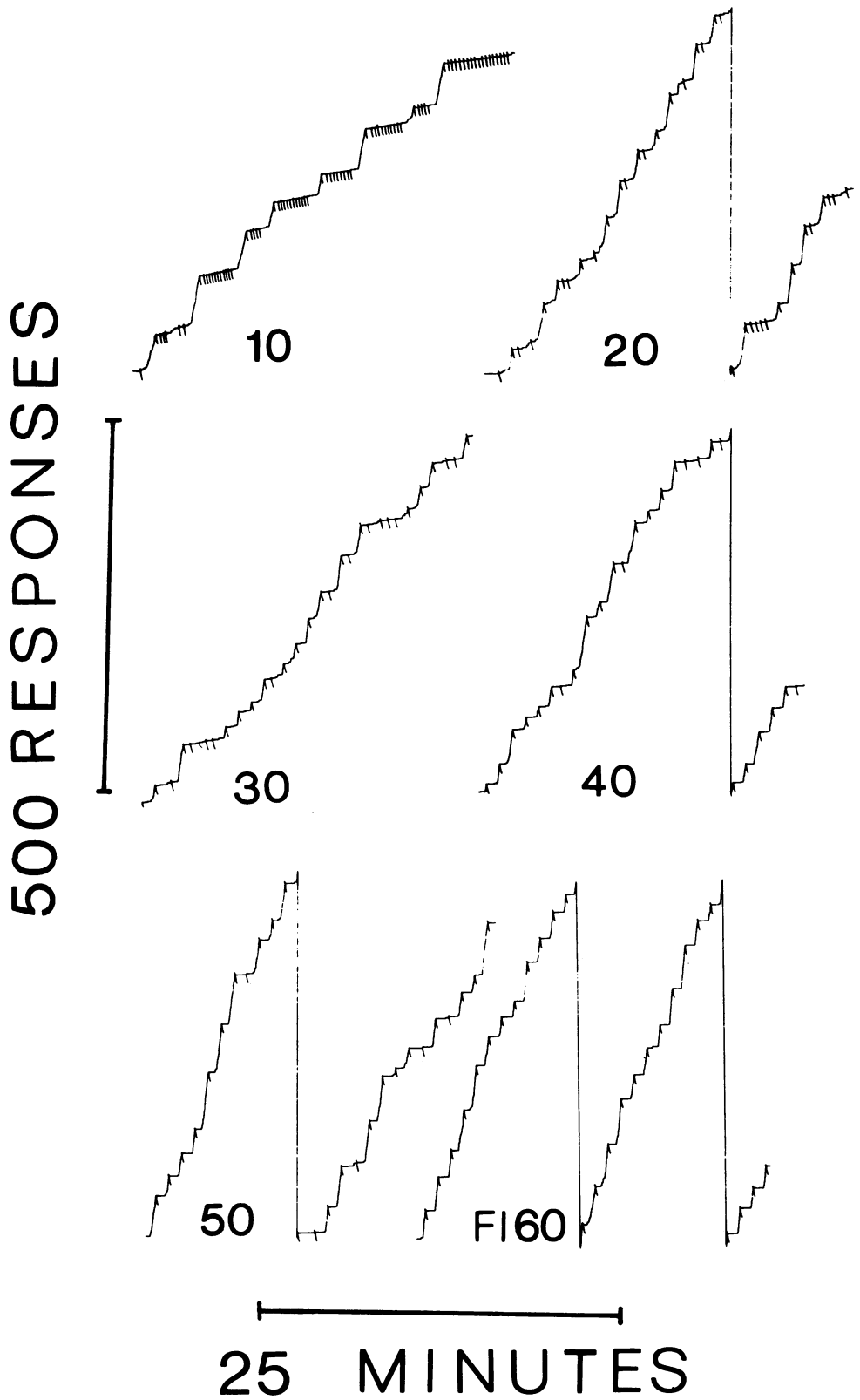
Experiment II(a): number of sessions, interquartile ranges of postreinforcement pauses (seconds), and mean interreinforcement interval (seconds) on each condition. BL₁: First Baseline FI 60-sec. BL₂: Second Baseline FI 60-sec.

Animal	Schedule alt FI 60		Interquartile Ranges of Pauses Following		Mean Interrein- forcement Interval
	IRT > X-sec X =	No. Ses- sions	FI rft.	IRT > X rft.	
P2	10	19	15.2-19.7	12.0-16.0	19.6
	20	17	18.0-23.0	17.2-21.0	44.6
	30	38	23.2-33.0	22.0-29.0	53.0
	40	12	27.7-38.0	28.2-34.2	57.8
	50	12	27.0-41.2	18.0-37.7	59.4
	BL ₁	18	25.0-44.5		60.0
	BL ₂	10	33.0-49.0		60.0
P8	10	18	12.2-18.0	13.0-18.0	19.4
	20	17	18.0-25.7	21.0-26.0	34.6
	30	37	28.0-35.2	29.0-33.0	44.6
	40	13	34.0-44.0	33.6-40.7	56.4
	50	12	18.0-44.0	37.0-45.0	57.8
	BL ₁	18	32.0-48.5		60.0
	BL ₂	10	31.5-48.0		60.0
P10	10	19	8.0-11.0	9.0-12.0	40.4
	20	17	8.0-19.0	7.2-19.0	54.6
	30	35	5.0-28.2	4.0-23.2	56.2
	40	12	19.5-34.0	20.5-32.0	58.6
	50	12	7.7-40.5	14.5-30.0	58.4
	BL ₁	18	20.5-37.0		60.0
	BL ₂	10	12.5-46.0		60.0
P13	10	19	9.0-11.5	9.2-12.2	35.2
	20	17	13.0-18.0	13.0-18.0	45.2
	30	37	16.0-25.0	14.0-22.0	57.8
	40	14	22.0-32.7	17.7-21.0	58.8
	50	12	14.7-25.0	*	60.0
	BL ₁	18	27.5-43.0		60.0
	BL ₂	10	15.5-28.5		60.0

*No interquartile ranges are shown since the number of postreinforcement pauses was small (<4 per session).

second FI 60-sec baseline schedule. The records are representative of the performance of other animals. Runs of successive IRT > t reinforcements occurred on low values of the IRT > t schedule, such IRT > t reinforcements being less frequent as the schedule value increased. The FI response pattern consisted mainly of characteristic scallops but there were also some break-and-run patterns, especially with high values of IRT > t.

Taking only the FI segments of performance, i.e., interreinforcement intervals with pauses shorter than the IRT > t criterion, Figure 4 shows the running rate and overall rate of responses as functions of the value of the IRT > t schedule. The running rate of



responses remained approximately the same with $IRT > t$ values up to 30 sec, but increased as a function of $IRT > t$ value beyond that (*cf.*, Lowe, *et al.*, 1974; Lowe and Harzem, 1977). Schedule effects were masked, however, in the overall rate measure, which remained more or less the same at all $IRT > t$ values. Such masking of relationships by the measure of overall rate has been previously observed in other situations; *i.e.*, Lowe *et al.* (1974), Lowe and Harzem, Priddle-Higson (1976), and Timberlake (1977).

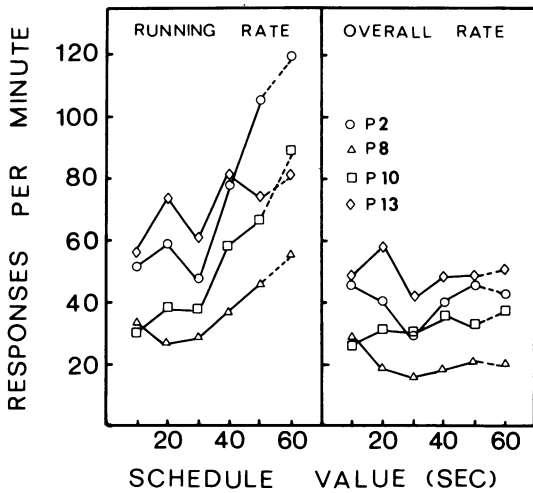


Fig. 4. Experiment II(a): mean running response rates, and overall response rates in the FI segments, (*i.e.*, interreinforcement intervals with pauses less than the $IRT > t$ criterion) of the *alt* FI $IRT > t$ schedules. Data points from the FI 60-sec condition (Second Baseline) are connected by broken lines. Data are from the last three sessions.

Under the alternative schedules, with all values of the $IRT > t$ schedule (except one data point for Animal P13), the proportion of pauses meeting the $IRT > t$ criterion was less than the proportion of such pauses on the simple FI 60-sec schedule (Figure 5). Thus, as in Experiment I, addition of the $IRT > t$ contingency shortened postreinforcement pauses. Even with the 10-sec criterion, for example, although almost all of the pauses on FI 60-sec were longer than 10 sec, fewer such pauses occurred when the $IRT > t$ 10-sec contingency was in effect.

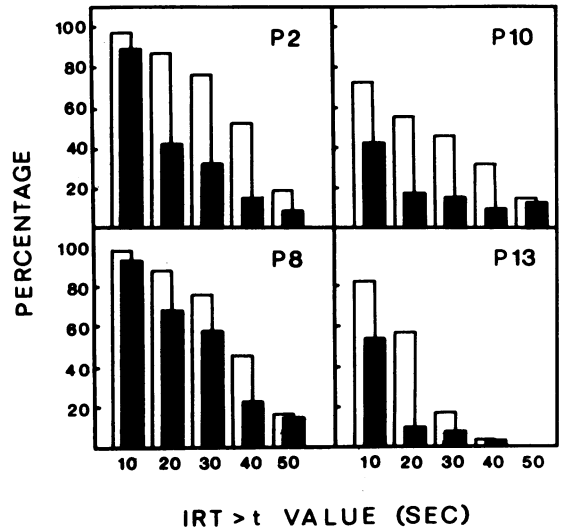


Fig. 5. Experiment II(a): percentage of pauses greater than the $IRT > t$ criterion under the simple FI 60-sec schedule (Second Baseline) shown by unfilled blocks, and when responses terminating such pauses were reinforced under *alt* FI $IRT > t$ schedules (filled blocks). Data are from the last three sessions under each $IRT > t$ value.

Figure 6 shows mean duration of all postreinforcement pauses as a function of $IRT > t$ value. These data are compared with the mean duration of postreinforcement pauses that were observed under simple $IRT > t$ schedules. (See procedure of Experiment II(b).) For all animals, the functions obtained with different values of the *alt* FI $IRT > t$ schedule were similar to the functions obtained with comparable values of the simple $IRT > t$ schedule, despite considerable differences in mean interreinforcement intervals between the two schedules (see Tables 2 and 4). The postreinforcement pause functions of Figure 6 are similar to those previously reported for interresponse times on temporal schedules (*cf.* Catania, 1970). Thus, it appears that pause durations in the present experiment were controlled entirely by the $IRT > t$ contingency.

There remains, however, the possibility that individual pauses may nevertheless have been differently affected, depending on whether they followed an FI run of responding or $IRT > t$ pause. Figure 7 shows that there was

Fig. 3. Experiment II(a): cumulative records obtained from Animal P2 in the last session with each *alt* FI $IRT > t$ schedule value, and under the second baseline FI 60-sec schedule. The numbers next to each record indicate the $IRT > t$ value.

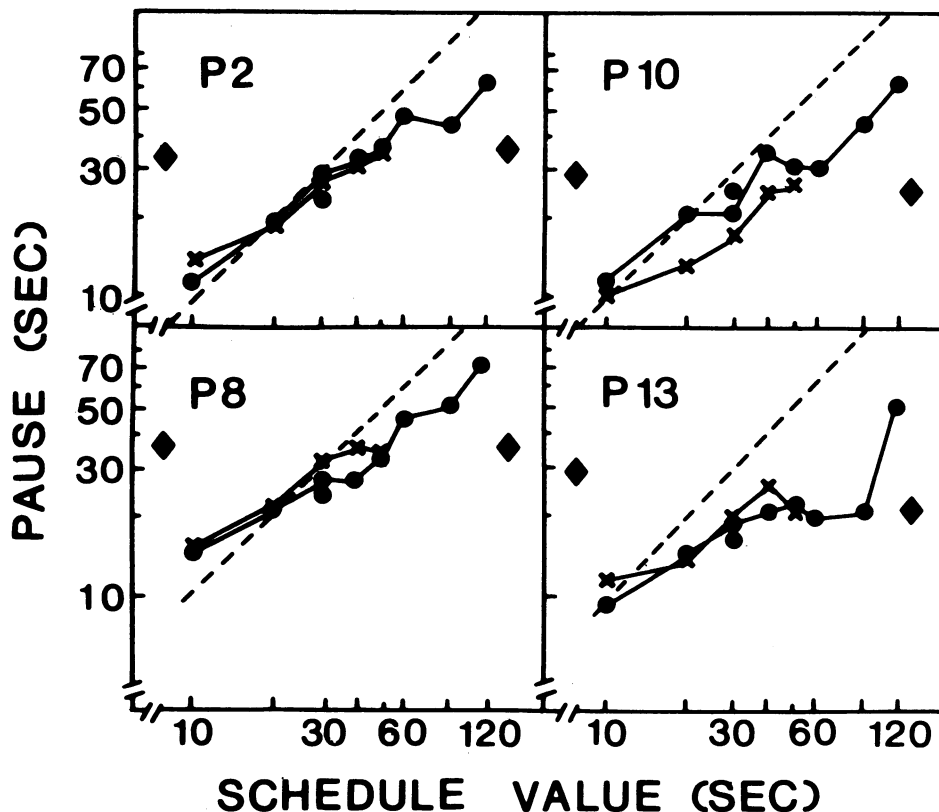


Fig. 6. Experiment II(a): mean duration of postreinforcement pauses as a function of $IRT > t$ schedule value in the *alt* FT $IRT > t$ schedule (crosses) and under simple $IRT > t$ schedules (filled circles). Unconnected circles indicate redetermination points for $IRT > t$ values. Unconnected diamonds in the left and right of each panel are pause durations under the First and Second Baseline FI 60-sec schedules respectively. The broken line indicates the $IRT > t$ criterion above which the response terminating the pause produced reinforcement. Note that both axes are log scales.

no such differential effect, at each schedule value the pauses being of similar duration irrespective of whether they were preceded by FI or $IRT > t$ reinforcement. Moreover, there was also no systematic relationship between the number of responses emitted in FI runs and the duration of the subsequent pause.

These findings were extended in the next experiment where the $IRT > t$ value was held constant and the FI value was systematically manipulated.

EXPERIMENT II(b): MANIPULATION OF THE FI PARAMETER

METHOD

Subjects and apparatus were the same as in Experiment II(a). Immediately following the final condition of Experiment II(a), the

animals were placed under an $IRT > 20$ -sec schedule until responding became stable (First Baseline). An FI contingency was then added, so that the schedule was *alt* FI X-sec $IRT > 20$ -sec. Thus, throughout the experiment, the $IRT > t$ value was 20 sec and the FI value (X) was 60, 30, 120, 15, 240, and 480 sec, in that order. Finally, 11 further sessions were conducted under the $IRT > 20$ -sec schedule (Second Baseline). Each schedule change was made after the stability criterion was met, the criterion being the same as in previous experiments. The number of sessions under each condition is shown in Table 3. All other details of the procedure were the same as in Experiment II(a).

On completion of this phase, the animals were placed under simple $IRT > t$ and FI schedules with all the schedules used in the alternative schedules of Experiments II(a)

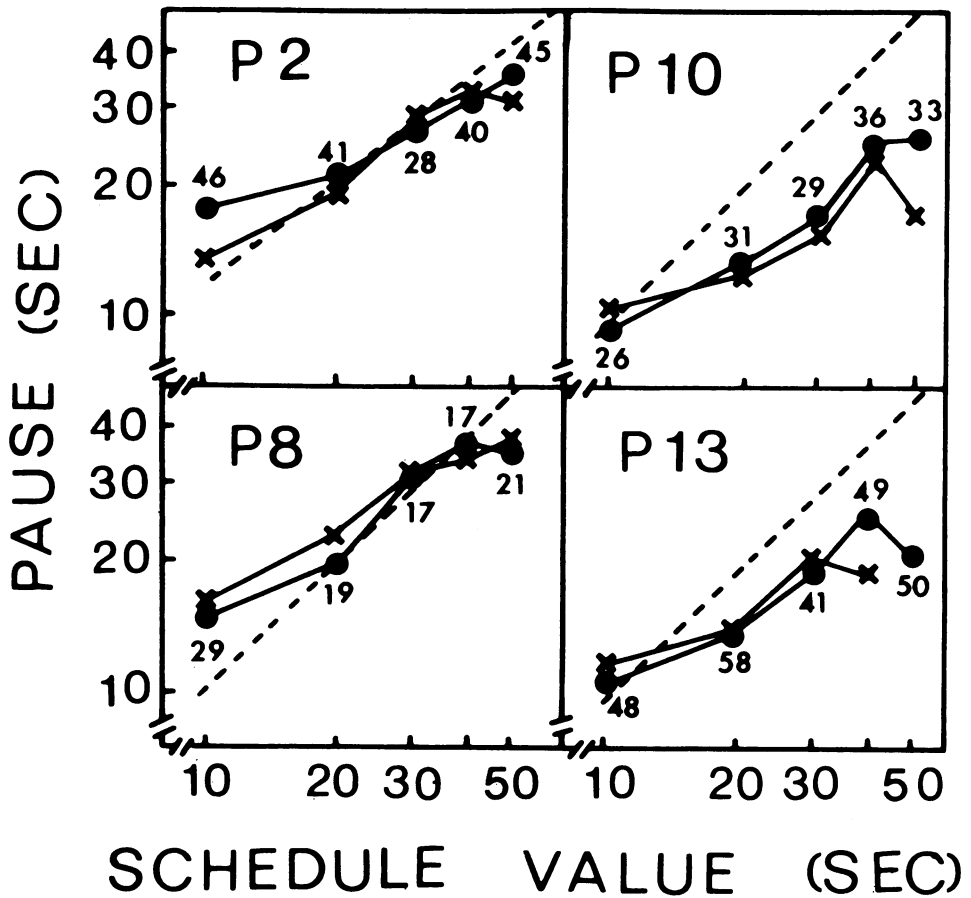


Fig. 7. Experiment II(a): mean duration of pauses following FI reinforcement (filled circles) and following IRT > t reinforcement (crosses). Numbers indicate the mean number of responses in the preceding FI run. Broken lines show the IRT > t criterion above which the response terminating the pause produced reinforcement. Note that both axes are log scales.

and II(b). Each schedule change was made after the stability criterion was met. The order of schedules, number of sessions on each schedule, interquartile ranges of the postreinforcement pauses, and mean interreinforcement interval on each condition are given in Table 4.

RESULTS AND DISCUSSION

Figure 8 shows sample cumulative records of the performance of Animal P2 in the last session of every schedule value. These records are representative of the performance of the other animals. With each value of the schedule, characteristic FI performance occurred, consisting mainly of scallops. As the FI value increased, there was a decline in the number of reinforcements that occurred under the IRT > t schedule in each session and in the overall frequency of reinforcement.

The running rate and overall rate of responses that occurred in the FI segments, *i.e.*, interreinforcement intervals with pauses shorter than the IRT > t criterion, are shown in Figure 9. Both running rate and overall rate were negatively accelerated decreasing functions of the FI value, (*cf.* Schneider, 1969; Starr and Staddon, 1974).

As in the previous experiments, the proportion of pauses that met the IRT > t criterion of 20 sec was greater under the simple FI schedules than under the comparable value of the *alt* FI IRT > t schedule (Figure 10); this was the case at all FI values, except for P13 with the 30-sec and 60-sec values. Figure 11 shows the mean duration of all postreinforcement pauses, regardless of FI or IRT > t reinforcement, as a function of FI schedule value. (See Table 3 for interquartile ranges.)

Table 3

Experiment II(b): number of sessions, interquartile ranges of postreinforcement pauses (seconds) and mean interreinforcement intervals (seconds) on each condition.

Animal	Schedule alt FI X-sec		Interquartile Ranges of Pauses Following		Interreinforcement Interval
	IRT > 20-sec X =	No. Sessions	FI rft.	IRT > 20 sec	
P2	15	10	8.6-12.1	*	16.4
	30	8	14.0-18.1	14.0-20.2	27.4
	60	10	13.9-19.9	13.8-30.6	42.9
	120	10	17.7-22.0	18.5-23.9	55.9
	240	15	14.0-18.7	17.6-22.1	122.6
	480	20	15.9-19.7	17.5-22.2	238.0
	BL ₁	18		21.3-25.6	35.6
	BL ₂	11		19.6-24.2	44.7
P8	15	10	9.6-11.4	*	16.5
	30	8	12.0-21.7	17.1-23.9	32.6
	60	10	14.0-20.0	16.0-23.0	41.3
	120	10	13.5-22.0	16.0-23.8	52.0
	240	15	12.0-22.0	17.1-23.2	84.9
	480	20	16.1-19.8	18.0-24.0	244.3
	BL ₁	18		13.7-22.4	54.2
	BL ₂	11		19.6-23.7	41.1
P10	15	10	4.1- 7.3	*	15.5
	30	8	7.2-10.9	8.2-11.8	29.3
	60	10	8.3-17.6	7.1-14.0	54.2
	120	10	10.0-20.3	7.0-18.1	97.5
	240	15	8.3-17.5	10.1-19.0	194.5
	480	20	6.8-18.9	*	383.3
	BL ₁	18		11.6-21.2	86.1
	BL ₂	11		4.7-18.2	102.3
P13	15	10	4.0- 9.1	*	15.5
	30	8	8.1-16.0	10.3-18.7	30.6
	60	10	7.7-15.9	12.2-18.9	53.3
	120	10	6.0-13.1	9.4-17.1	107.9
	240	15	6.9-15.3	*	225.2
	480	20	9.3-17.5	*	418.6
	BL ₁	18		7.2-17.1	123.8
	BL ₂	11		12.7-24.0	54.8

*Interquartile ranges are not given since the number of pauses was small (<4 per session).

These data are compared with the postreinforcement pause durations observed under the simple FI schedule, with comparable schedule values. Under simple FI schedules, the postreinforcement pause duration was an increasing function of the schedule parameter (cf. Lowe and Harzem, 1977). The pause durations in the alt FI IRT > t schedules, however, were maintained at or below the IRT > t value of 20 sec regardless of the value of the FI schedule, even with values as long as 480 sec, and were of the same duration of pauses under the baseline IRT > 20-sec schedule. Thus, in this experiment, as well as in

Experiment II(a), the IRT > t contingency set the upper limit to the durations of the postreinforcement pauses. Table 3 shows that, contrary to some suggestions (Berryman and Nevin, 1962; Nevin, 1973), the duration of the postreinforcement pause was not, on the alt FI IRT > t schedules, directly related to the arithmetic mean interreinforcement interval.

As in Experiment II(a), the individual pauses were not differently affected according to whether they followed an FI run of re-

Table 4

Number of sessions, interquartile ranges of postreinforcement pauses (seconds), and mean interreinforcement intervals (seconds) for simple FI and IRT > t schedules. The order of schedule values is shown top to bottom. IRT > t schedules were run after completion of al FI sessions.

Animal	FI (sec)	No. Sessions	Interquartile Ranges of Pauses	Interreinforcement Interval	
P2	60	14	40.8- 57.4	60.0	
	30	12	15.0- 28.7	30.0	
	120	18	36.5- 68.0	120.0	
	480	17	97.0-195.5	480.0	
	15	12	9.0- 15.0	16.0	
	240	18	43.5-100.6	240.0	
	120	16	43.4- 85.4	120.0	
	480	24	99.9-224.5	480.0	
	15	8	9.0- 15.8	16.0	
	P8	60	14	22.9- 43.6	60.0
		30	12	16.8- 24.2	30.0
		120	18	39.0- 75.0	120.0
		480	17	66.0-191.2	480.0
		15	12	9.8- 13.4	16.0
		240	18	49.8-107.5	240.0
120		16	43.5- 81.5	120.0	
480		24	82.2-193.6	480.0	
15		8	8.5- 15.5	16.0	
P10		60	14	21.7- 44.7	60.0
		30	12	9.3- 17.6	30.0
		120	18	31.0- 70.5	120.0
		480	17	59.0-130.0	480.0
		15	12	5.5- 9.6	15.0
		240	18	41.5- 97.5	240.0
	120	16	36.4- 84.4	120.0	
	480	24	36.0-117.5	480.0	
	15	8	5.1- 8.6	15.5	
	P13	60	14	8.9- 19.6	60.0
		30	12	5.5- 12.1	30.0
		120	18	15.5- 48.5	120.0
		480	17	19.0- 81.0	480.0
		15	12	5.0- 10.0	15.0
		240	18	15.1- 30.1	240.0
120		16	15.3- 50.6	120.0	
480		24	14.8- 30.4	480.0	
15		8	5.5- 8.3	15.5	

Table 4 continued

Animal	IRT > t (sec)	No. Sessions	Interquartile Ranges of Pauses	Interreinforcement Interval
P2	30	14	18.2-28.4	214.3
	20	10	18.6-21.3	65.2
	40	12	31.5-39.1	461.5
	10	8	9.0-12.7	18.7
	50	14	33.1-40.0	600.0
	30	10	26.8-31.2	120.0
	60	12	34.5-35.3	537.1
	120	14	39.2-81.6	1369.0
	90	12	27.6-54.9	714.0
P8	30	14	21.3-33.0	181.8
	20	10	18.3-22.7	46.1
	40	12	24.0-22.7	240.0
	10	8	10.0-16.8	20.0
	50	14	20.3-41.7	375.0
	30	10	21.7-31.3	100.0
	60	12	22.9-55.9	562.1
	120	14	36.2-96.0	843.0
	90	12	36.1-60.7	588.0
P10	30	14	17.8-28.7	157.9
	20	10	18.9-21.3	46.1
	40	12	28.8-39.9	352.9
	10	8	9.6-12.3	19.4
	50	14	15.6-40.3	428.6
	30	10	16.0-26.8	175.0
	60	14	17.5-37.4	687.4
	120	14	*	2083.7
	90	12	24.2-64.5	847.8
P13	30	12	12.1-19.6	230.8
	20	10	9.4-19.4	67.4
	40	12	11.2-19.4	260.9
	10	8	6.9-26.6	27.3
	50	14	14.0-23.7	290.9
	30	12	10.7-22.8	150.0
	60	14	12.6-22.5	876.0
	120	14	*	2229.4
	90	12	14.5-22.5	1813.0

*Interquartile ranges are not given since the number of pauses was small (<4 per session).

sponding on an IRT > t pause. Figure 12 shows that at each FI value the pauses were of similar duration, regardless of whether they were initiated by an FI or an IRT > t reinforcement. There was also no relationship between the number of responses in an FI run and the duration of the postreinforcement pause that followed that run.

GENERAL DISCUSSION

Control of the Postreinforcement Pause

The present results, especially those of Experiment I, provide further evidence that the duration of the postreinforcement pause is controlled by the discriminative effect of the

event initiating that pause (*cf.* Cruse *et al.*, 1966; Ferster and Skinner, 1957; Skinner, 1938). In simple schedules, *i.e.*, where only responses and reinforcement are involved and not other discriminative stimuli, the delivery of food can function both as the discriminative stimulus initiating the pause, and in marking the end of the interval to which the postreinforcement pause is related (see Harzem, Lowe, and Priddle-Higson, 1978). It is not necessary, however, for these two functions to be combined in the same stimulus; the event initiating the pause may be a stimulus other than the reinforcer. Zeiler (1972) presented a different stimulus in place of the reinforcer on a percentage of the occasions under an FI schedule, and found that the FI pattern of responding was maintained in the intervals following the stimulus, as well as following reinforcement.

Given that the reinforcer functions as a discriminative stimulus in initiating the postreinforcement pause, there remains the question of how the duration of that pause is determined. In the present study, when responses terminating a pause that exceeded a criterion duration were reinforced, the proportion of such pauses occurring on the FI schedule decreased, rather than increased. A plausible explanation of this effect is that in those situations where the FI value was greater than the IRT > t value, the event initiating the pause set the occasion for pausing for a period related to the IRT > t criterion and not exceeding it. That is to say, whether reinforcement controls the pause that occurs on the FI schedule or on the IRT > t schedule is determined by the shorter of the two pauses.

Catania and Reynolds (1968), using two-valued FI schedules where responses were reinforced according to either a long FI (240 sec) or a short FI (30, 90, or 210 sec, across conditions), reported results similar to the present findings. When responses were reinforced at 30 and 240 sec, response rates increased to an asymptote near 30 sec, then declined, and then increased again as 240 sec approached. Even a low probability of reinforcement at an early time increased substantially the probability of a response at that time (see also Ferster and Skinner, 1957). The present data showed a similar relationship when the early reinforcement opportunity was

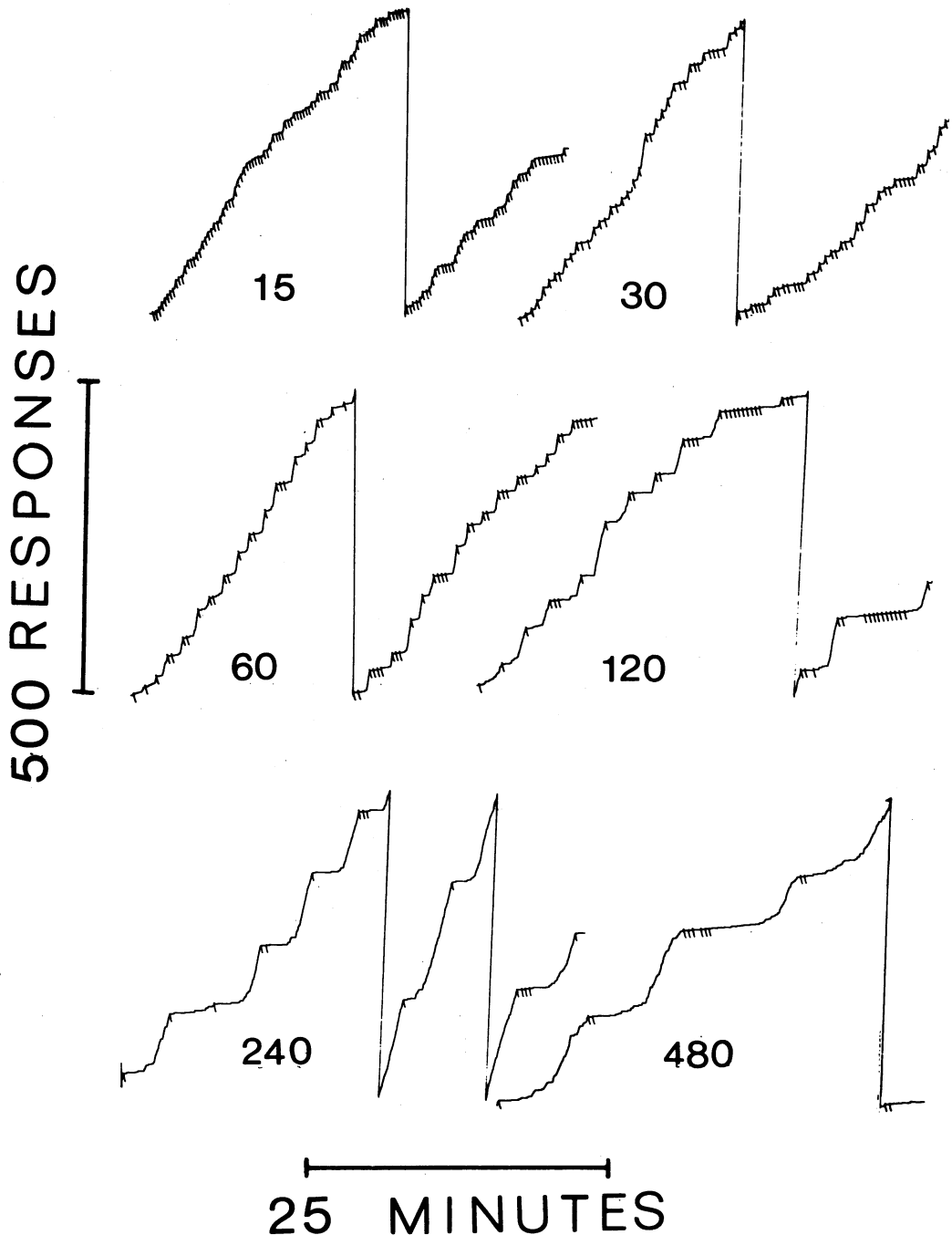


Fig. 8. Experiment II(b): cumulative records obtained from Animal P2 in the last session with each *alt* FI IRT > *t* schedule value. The numbers next to each record indicate the FI value.

scheduled by an IRT > *t* dependency. These data are thus consistent with the observation that the probability of a response increases as a function of proximity to the time at which that response is reinforced (Catania and

Reynolds, 1968; Shull and Guilkey, 1976). Lattal and Bryan (1976) have also shown that when response-independent food is presented early in the interval on FI schedules, the duration of the postreinforcement pause is

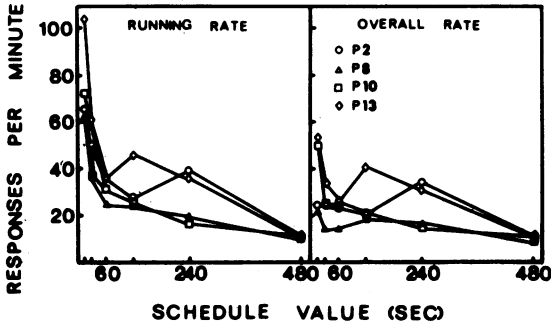


Fig. 9. Experiment II(b): mean running response rates and overall response rates in the FI segments, i.e., interreinforcement intervals with pauses shorter than the $IRT > t$ criterion of the *alt* FI $IRT > t$ schedules. Data are from the last three sessions under each schedule value.

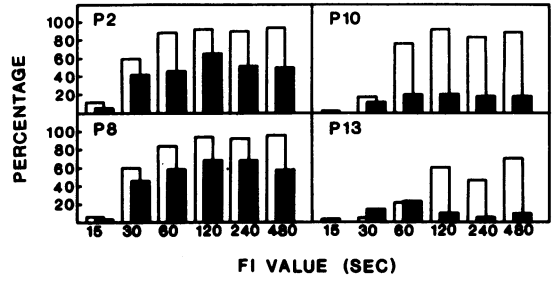


Fig. 10. Experiment II(b): percentage of pauses longer than the $IRT > t$ criterion of 20 sec under the simple FI schedules (unfilled blocks) and under comparable *alt* FI $IRT > t$ schedules (filled blocks). Data are from the last three sessions under each FI Value.

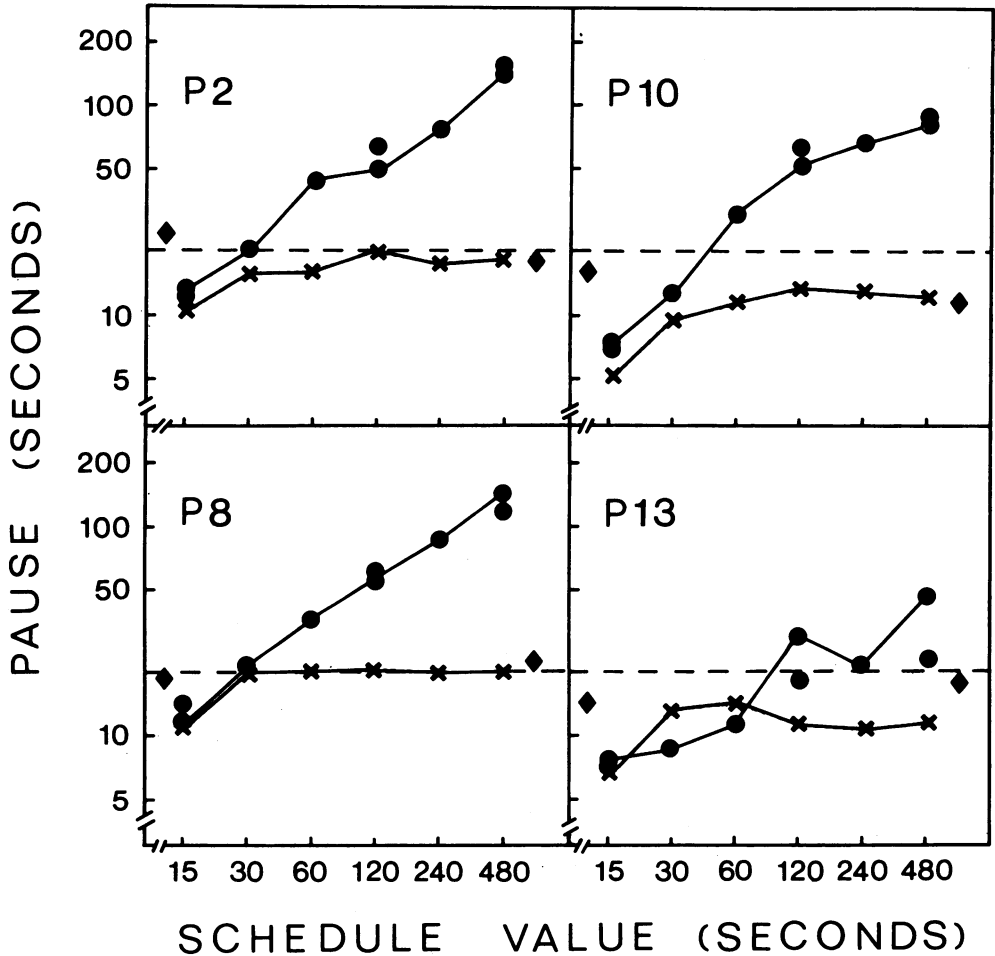


Fig. 11. Experiment II(b): mean duration of postreinforcement pauses as a function of FI schedule value in the *alt* FI $IRT > t$ schedule (crosses) and under simple FI schedules (filled circles). Unconnected circles indicate redetermination points for FI values. Unconnected diamonds in the left and right of each panel are pause durations under the First and Second Baseline $IRT > t$ schedules respectively. The broken line indicates the $IRT > t$ criterion above which the response terminating the pause produced reinforcement. Note that both axes are log scales.

greatly reduced. In that study, both the reinforcer and the response-independent food were identical and there was no evidence that the animals could distinguish between the two, *i.e.*, a "confusion effect" was present, similar to that observed in Experiment I. Shull and Guilkey (1976) attempted directly to reinforce pausing under FI schedules by providing response-independent food on a variable-time (VT) schedule, food delivery being dependent on the absence of responding following FI reinforcement; a different key-color was correlated with the VT schedule. Using this procedure, Shull and Guilkey found that the duration of the postreinforcement pause under the FI schedule was unaffected by the delivery of response-independent food (see also Buchman and Zeiler, 1975). As was the case in the present experiments, long post-reinforcement pauses failed to occur despite the increase in reinforcement rate that this would have produced.

The Natural Rate Hypothesis

Under schedules where reinforcement opportunity is spaced in time, *e.g.*, under FI and $IRT > t$ schedules, most organisms emit considerably more responses than required for reinforcement. Indeed, under $IRT > t$ sched-

ules, excessive responding occurs despite the fact that it results in loss of reinforcements. Pigeons are notable for their inability to withhold their key pecks under $IRT > t$ schedules (Harzem, 1969; Kramer and Rilling, 1970; Reynolds, 1966). Moreover, under this schedule response bursts, *i.e.*, two or more responses occurring in very rapid succession, are observed even though such bursts are never reinforced. To account for these phenomena, Staddon (1972, 1975) suggested that there is a natural response rate for a given species and response topography, and that when an organism is required to respond at a low rate, it at times responds rapidly in order to bring up the response rate to its natural level. On the basis of this hypothesis, it would be expected that under the *alt* FI $IRT > t$ schedules a pause long enough to meet the $IRT > t$ criterion would be more likely to occur following an FI response run than following a $IRT > t$ pause (*cf.* Staddon, 1975). No such relationship was observed, however, in the present experiments. Moreover, taking only the pauses that followed FI runs, such pauses were not related to the number of responses that occurred in the preceding FI run. Also, Ferraro, Schoenfeld, and Snapper (1965) reported that under $IRT > t$ schedules, an

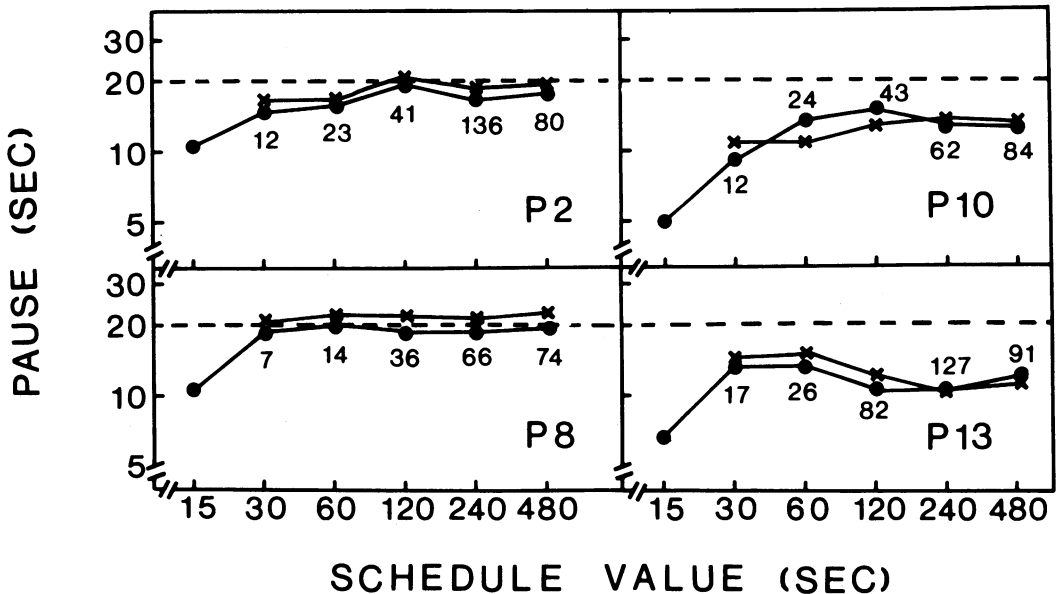


Fig. 12. Experiment II(b): mean duration of pauses following FI reinforcement (filled circles) and following $IRT > t$ reinforcement (crosses). Numbers indicate the mean number of responses in the preceding FI run. Broken lines show the $IRT > t$ criterion above which the response terminating the pause produced reinforcement. Note that both axes are log scales.

IRT long enough for reinforcement is more probable following a similarly long IRT than following a short, unreinforced IRT (See also Harzem *et al.*, 1975). It would appear, therefore, that characteristics of performance under temporally based schedules cannot be accounted for by reference to natural response rates.

Conclusion

Ferster and Skinner (1957) suggested that under FI schedules, reinforcement functions as a discriminative stimulus setting the occasion for a period without responding (*cf.* Dews, 1970; Skinner, 1938). This kind of discriminative control is also observed under $IRT > t$ schedules (Harzem *et al.*, 1975), and with stimuli other than reinforcers (Davey, Harzem, and Lowe, 1975; Zeiler, 1972). The present study provided further evidence of such control, and evidence as to the determination of the duration of the period of not responding. It appears that the duration of a postreinforcement pause is related to the contingencies operating at that particular time, signalled by the particular reinforcer that initiated that pause. Where more than one temporal contingency is in operation, the pause is not the result of some averaging process; what prevails is the contingency controlling the shortest pause.

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